# Nutrients, Suspended Sediment, and Pesticides in Water of the Red River of the North Basin, Minnesota and North Dakota, 1990-2004

By V. G. Christensen

Prepared in cooperation with the Minnesota Pollution Control Agency

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# Conversion Factors

## Inch/Pound to SI

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| inch (in.) | 2.54 | centimeter (cm) |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| | Area | |
| acre | 0.4047 | hectare (ha) |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |
| | Flow rate | |
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second ($m^3/s$) |
| | Mass | |
| pound, avoirdupois (lb) | 0.4536 | kilogram (kg) |
| | Hydraulic gradient | |
| foot per mile (ft/mi) | 0.1894 | meter per kilometer (m/km) |
| | Application rate | |
| pounds per acre per year [(lb/acre)/yr] | 1.121 | kilograms per hectare per year [(kg/ha)/yr] |

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C=(°F-32)/1.8

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

# Nutrients, Suspended Sediment, and Pesticides in Water of the Red River of the North Basin, Minnesota and North Dakota, 1990–2004

By Victoria G. Christensen

## Abstract

Nutrient, suspended sediment, and pesticide data from 1990 through 2004 in the Red River of the North Basin were compiled, summarized, and compared to historical data. Streamflow varied widely throughout the basin during the 1990–2004 study period. For 19 of 22 streamflow sites, median annual streamflow during the study period exceeded the long-term average streamflow. High streamflow can have a substantial effect on water quality. In water samples from selected surface-water sites, nitrite plus nitrate concentrations ranged from less than 0.005 to 7.7 milligrams per liter; total Kjeldahl nitrogen concentrations ranged from 0.1 to 7.5 milligrams per liter; total phosphorus concentrations ranged from less than 0.005 to 4.14 milligrams per liter; and dissolved phosphorus concentrations ranged from 0.003 to 4.13 milligrams per liter. Surface-water samples from the Pembina River Basin generally had higher nitrite plus nitrate, total phosphorus, and suspended sediment concentrations compared to samples from other Red River Basin sites. Historical data from 1970 through 1990 showed relatively high nitrite plus nitrate and suspended sediment concentrations in samples from some Pembina River sites; in contrast to the 1990–2004 period, total phosphorus concentrations from the 1970–90 period generally were highest at Red River of the North sites. Nitrate concentrations in ground-water samples for the 1990–2004 period were highest in Sheridan County, North Dakota and Marshall and Otter Tail Counties in Minnesota. Concentrations of nitrate in ground water in Marshall and Otter Tail Counties corresponded to relatively high reported fertilizer applications during 2002; however, Sheridan County did not have the high fertilizer applications in 2002 compared to other North Dakota and Minnesota counties. The most frequently detected pesticides or pesticide metabolites were 2,4-D, bentazon, deethylatrazine, metolachlor, picloram, and triallate in surface water and alachlor ethanesulfonic acid (ESA), atrazine, deethylatrazine, picloram, and triazine in ground water. None of the most frequently detected pesticides or metabolites sampled and analyzed by the U.S. Geological Survey or available in the U.S. Environmental Protection Agency Storage and Retrieval System (STORET) during 1990–2004 were detected frequently during 1970-90, with the exception of 2,4-D.

## Introduction

The Red River of the North (herein referred to as the Red River) Basin covers parts of South Dakota, North Dakota, Minnesota (fig. 1), and flows north into Canada where it drains into Lake Winnipeg. The basin is rich in agriculture. Nutrients, such as nitrogen and phosphorus, are applied in the form of fertilizers to increase agricultural productivity. Pesticides also are used in abundance (Minnesota Department of Agriculture and Minnesota Agricultural Statistics Service, 2005; Zollinger and others, 2006). Nutrients, suspended sediment, and pesticides often are associated with sediment runoff from farm fields.

A comprehensive report, *Nutrients, Suspended Sediment, and Pesticides in Waters of the Red River of the North Basin, Minnesota, North Dakota, and South Dakota, 1970–1990* by Tornes and Brigham (1994), summarized water quality and related data collected by selected agencies in the Red River Basin from 1970–90. Because there is continued concern about agricultural chemicals in the Red River Basin and there has been considerable data collected since 1990, the U.S. Geological Survey (USGS) and the Minnesota Pollution Control Agency (MPCA) cooperated on a study to compile, review, and summarize available data collected from 1990 through 2004 by several agencies on sediment and agricultural chemicals in the Red River Basin in northwestern Minnesota and eastern North Dakota.

### Purpose and Scope

The purpose of this report is to compile, review, and summarize available data on nutrients, suspended sediment, and pesticides in the Red River Basin in northwestern Minnesota and eastern North Dakota collected during 1990–2004. Data for this compilation includes surface- and ground-water data collected for a variety of sampling programs with different objectives and methods. The constituents described in this report are nitrite plus nitrate nitrogen, nitrate nitrogen, total Kjeldahl nitrogen, total phosphorus, dissolved phosphorus, suspended sediment, synthetic organic pesticides, and pesticide metabolites. The data compiled in this report also will be compared to a previous basin-wide analysis of water-quality data (Tornes and Brigham, 1994). Information from this report will provide a basis for future water-quality studies in the basin.

## Environmental Setting

The Red River Valley was formed when glaciers deposited 150 to 300 feet (ft) of unconsolidated material over much of the basin (Tornes and Brigham, 1994). The land is mostly flat with gentle slopes, lakes, and wetlands at the margins. Land-surface altitudes in the basin range from about 2,350 ft in the extreme western part of the basin to about 750 ft where the Red River crosses the international boundary into Canada (Stoner and others, 1993).

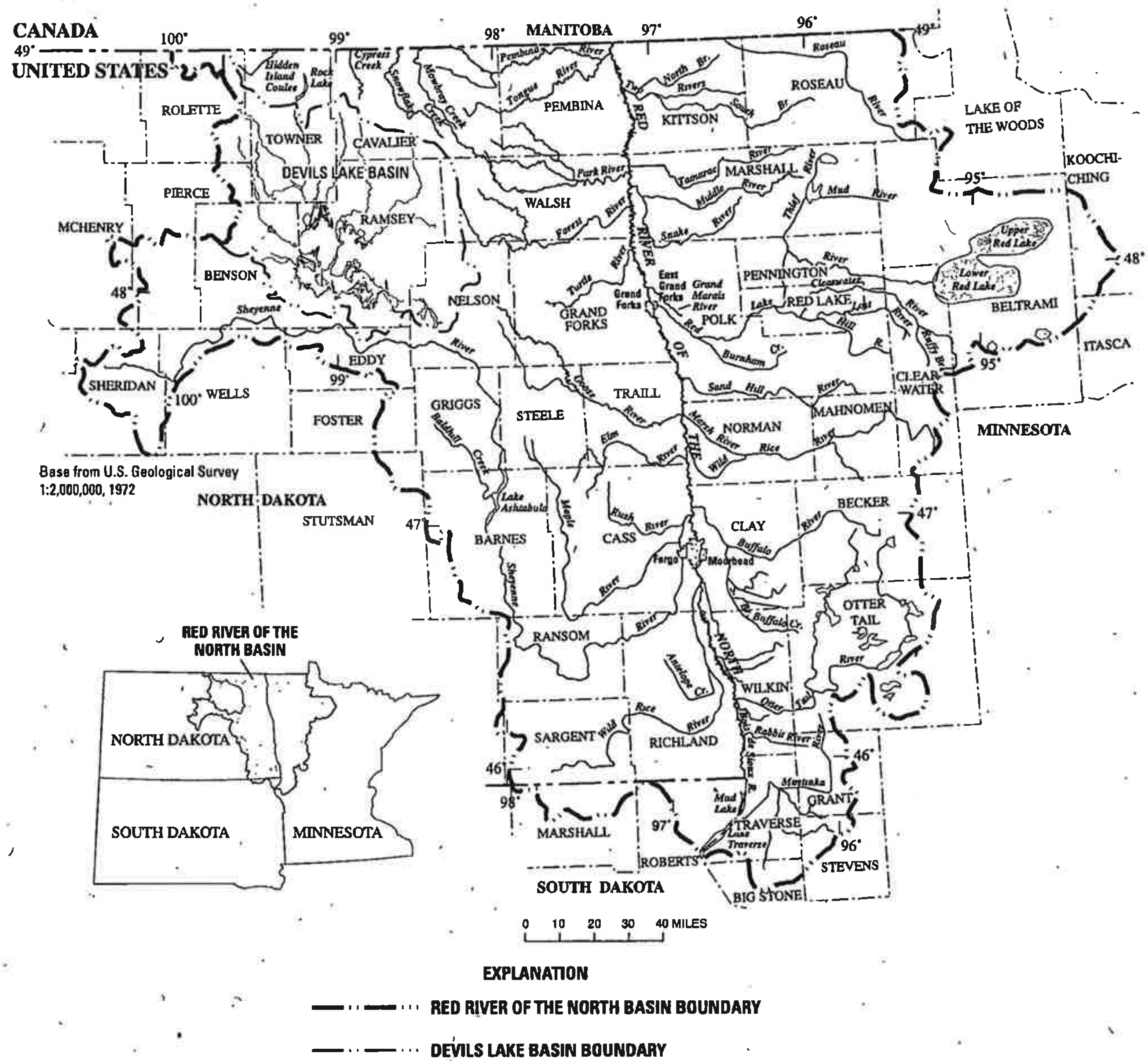


**Figure 1.** Location of the Red River of the North Basin in Minnesota and North Dakota.

Soils range from heavy, poorly drained clays and silts to light, well-drained sands (Stoner and others, 1993). Black, fine-grained soils are found throughout the basin. Because of the superior quality of soils, land use is primarily agricultural (74 percent, Stoner and others, 1993) of which 66 percent (Stoner and others, 1993) is cropland. Crops grown include barley, corn, dry beans, sugarbeets, soybeans, sunflower seeds, and wheat (U.S. Department of Agriculture, 2002). Livestock in the basin includes cattle, hogs, pigs, and sheep (U.S. Department of Agriculture, 2002).

The physiographic areas in the basin were first described by Anderson (1967) and include Drift Prairie, Red River Valley Lake Plain, Lake-Washed Till Plain, and Moraine (fig. 2). Tornes and others (1997) described the physiographic areas for the Red River Basin as follows: the Drift Prairies are an area of low rolling hills and prairie, with many prairie-pothole wetlands; the Red River Valley Lake Plain is an extensive area of flat land mostly comprised of clays and silts deposited by Glacial Lake Agassiz; the Lake-Washed Till Plain is a relatively flat upland area having extensive wetlands and peat deposits; and, the Moraine consists mostly of lakes and woodlands. The type of physiography can play heavily on the land uses that are established in an area. Land use, in turn, can be related to water quality.

From the confluence of the Bois de Sioux and Otter Tail Rivers, the Red River flows north, forming the border between North Dakota and Minnesota, into Canada, and ultimately into Lake Winnipeg in Manitoba, Canada. The study area includes 394 river miles to the United States-Canadian border (Tornes and Brigham, 1994). The slope of the main channel averages only about 0.5 feet per mile (ft/mi) (River Keepers, 2003). Seventy-five percent of the annual flow comes from the eastern tributaries (Tornes and Brigham, 1994) as a result of topography as well as regional patterns in precipitation, evaporation, and soils. Flooding in the spring can be a major problem (U.S. Geological Survey, 2001) and seasonal variability in streamflow is high (Vecchia, 2005). The drainage of the Red River Basin also includes the Devils Lake Basin, which is a closed basin except during extreme conditions. However, due to rising lake levels in Devils Lake and the construction of an emergency outlet to the Sheyenne River (Devils Lake Basin Joint Water Resources Board and North Dakota State Water Commission, 2006), it is important to consider the Devils Lake Basin as hydrologically connected to the Red River Basin and, thus, contributing to the water quality of the basin.

Sand and gravel aquifers occur in the glacial drift that underlies much of the Red River Basin. Regionally, the water moves toward the Red River. Many of the bedrock and glacial drift aquifers are hydraulically connected to streams in the region (Tornes and Brigham, 1994). Water levels in wells in glacial drift aquifers generally fluctuate less than 3 feet per year (Stoner and others, 1993, p. 601).

A recent study (River Keepers, 2003) has shown that nitrite and nitrate concentrations during 2001–2003 in water from the Red River generally were less than 1.0 milligrams per liter (mg/L). The MPCA uses the U.S. Environmental Protection Agency (USEPA) limit of 10 and 1.0 mg/L for nitrate and nitrite in public water supplies, respectively, whereas the North Dakota Department of Health (NDDH) has an interim guideline of 1.0 mg/L for nitrate. Nitrite plus nitrate concentrations increased significantly from the mid-1980s to the mid-1990s for several Red River locations (Vecchia, 2005). Increasing concentrations for main-stem Red River sites may have been caused by human activities. Phosphorus concentrations for the Red River from 2001 to 2003 were greater than the 0.1 mg/L North Dakota Department of Health standard (River Keepers, 2003). Only small amounts of pesticides have been detected in surface water—usually less than 2 percent of the amount applied (Tornes and Brigham, 1995). Surface-water quality in the Red River Basin varies seasonally (Red River Basin Board, 2001). Generally, concentrations of dissolved chemical constituents are low during spring runoff and after rain events (Tornes and Brigham, 1994). During low flow, the water quality reflects the chemistry of the glacial-drift aquifer system.

Ground water in surficial aquifers commonly is a calcium-bicarbonate type (Tornes and Brigham, 1994). Water deeper in the glacial drift is primarily a magnesium-sulfate type. Water in sedimentary bedrock aquifers is a sodium-chloride type and is characterized by dissolved solids concentrations of 1,000 mg/L or more (Tornes and Brigham, 1994). A previous study showed that ground water from the eastern part of the Red River Basin had significantly higher concentrations of nitrate and agricultural herbicides than did ground water from the western part of the basin (Cowdery, 1995). Agricultural land use and soil texture explain pesticide and nutrient distribution, respectively (Cowdery, 1995).

The Red River Basin has a subhumid to humid continental climate. North Dakota's climate is characterized by large temperature variations, irregular precipitation, and nearly continuous wind (Enz, 2003). The annual mean temperature in the area of Fargo, N.Dak. and Moorhead, Minn. is about 40 degrees Fahrenheit (°F) (Owenby and others, 1992). However, the annual mean temperature can be misleading because of the large temperature variations. The January average temperature is about 0 °F and the average temperature in July is about 65 °F (Enz, 2003). The near continuous wind often results in large day to day temperature fluctuations in all seasons (Enz, 2003). Mean annual precipitation is about 21 inches (in.) (Owenby and others, 1992), most of which occurs during April through September. Precipitation in the basin generally increases from west to east. The greatest annual precipitation for the period of record for Fargo (34.75 in.) occurred in 2002 (Godon and Godon, 2002).

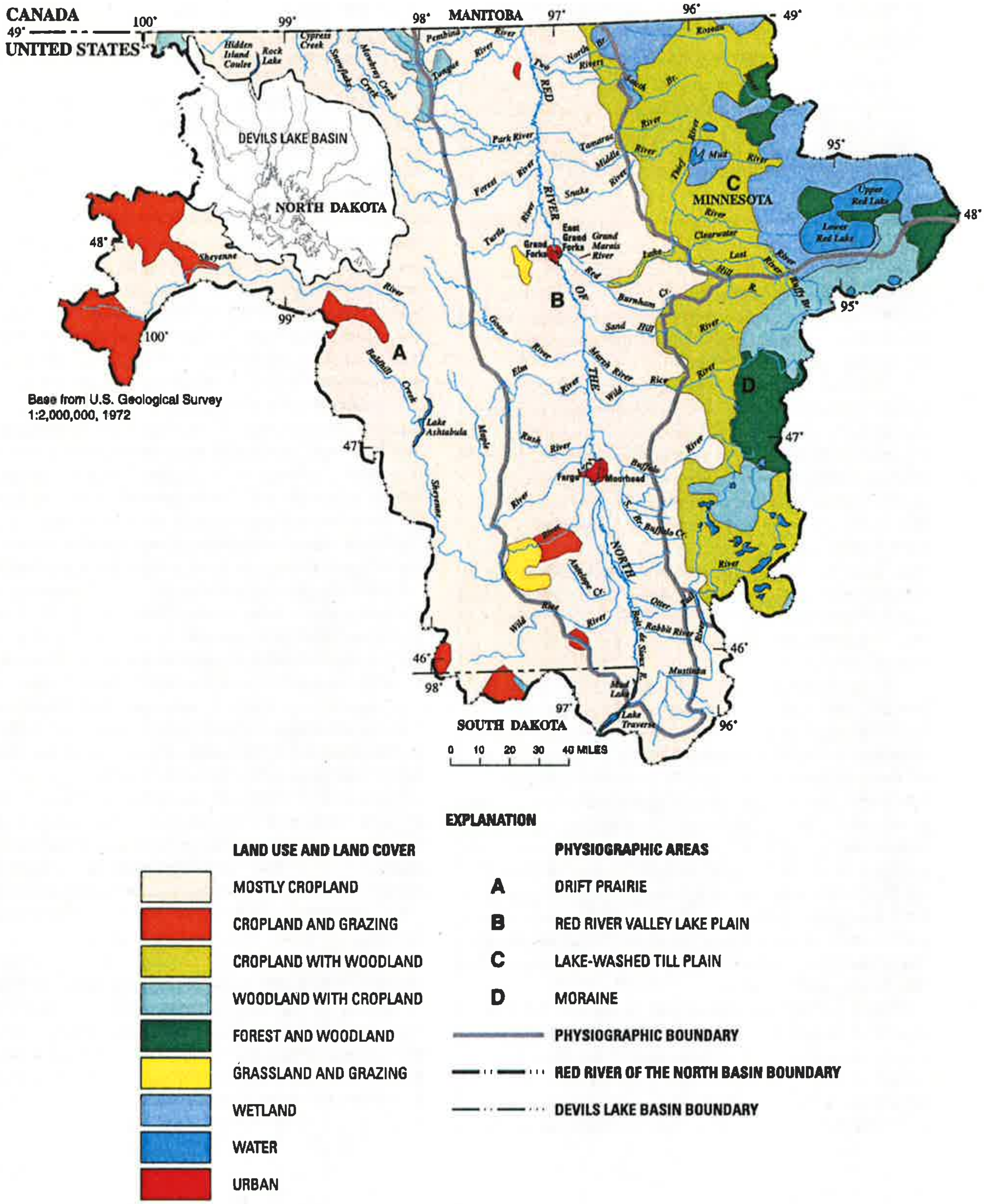


**Figure 2.** Land use and land cover and physiographic areas in the Red River of the North Basin.

## Uses and Sources of Nutrients, Sediment, and Pesticides

Nutrients, such as nitrogen and phosphorus, are essential for the growth and reproduction of plants. Excess nutrients in water, however, can fertilize naturally occurring aquatic plants and cause excessive algal growth. This may produce taste and odor problems in drinking water, reduce the aesthetic and recreational value of the water, and stress aquatic organisms by the depletion of dissolved oxygen when algal blooms die (Christensen and Pope, 1997). Sources of nutrients in the Red River Basin include fertilizers, sewage treatment plants, septic systems, combined sewer overflows, sediment mobilization, runoff from animal feeding operations, atmospheric transport, and nutrient recycling from sediments to the water column (Red River Basin Board, 2001).

Application of nutrients to crops as manure and commercial fertilizer can result in increased nutrients in surface and ground water. Estimates of fertilizer applications are provided for the counties in the Red River Basin (table 1). The total nutrient input from fertilizer applications is calculated by adding input from commercial fertilizers to inputs from manure. Commercial fertilizer and total application is greatest in Polk County, Minn. and Cass County, N. Dak. Both of these counties border the main stem of the Red River (fig. 1). Previous research (Tornes and Brigham, 1994) also identified counties adjacent to the Red River as having the greatest fertilizer applications. Manure application is greatest in Otter Tail County, Minn.

Land use influences the movement of nutrients from land to surface water (Bourne and others, 2002). In the Red River Valley an estimated 1.56 pounds per acre per year [(lb/acre)/yr] of total nitrogen and 0.20 (lb/acre)/yr of total phosphorus are exported from pasture and 2.81 (lb/acre)/yr nitrogen and 0.58 (lb/acre)/yr total phosphorus are exported from cropland (Bourne and others, 2002). Commercial fertilizers and manure contain varying ratios of nitrogen to phosphorus (Tornes and Brigham, 1994). In several large rivers, nitrogen to phosphorus (N:P) ratios were significantly related to the N:P ratios in fertilizer applied to the basins (Caraco, 1995, p. 242). Due to the concern about phosphorus loading to the lakes in Minnesota, a phosphorus ban on lawn fertilizers was passed in 2005 (Minnesota, State of, 2005).

Land use and agricultural practices also can affect the amount of suspended sediment in surface water. Sediment is an important indicator of water quality because of solute-sediment interactions (between sediment and some organic compounds, for example). Excess sedimentation occurs in areas of larger municipal and industrial centers and in regions affected by agricultural and urban runoff (Red River Basin Board, 2001). Sediment erosion can be increased by cultivation practices and by livestock that trample stream banks (Stoner and others, 1993).

Pesticides applied to crops mainly include herbicides, fungicides, and insecticides. Other pesticides include fumigants, growth regulators, and defoliants. A 1997 survey (Gianessi and Marcelli, 2000) indicates that the pesticides used in the greatest abundance in Minnesota and North Dakota are 2,4-D, MCPA, and dicamba (acres treated, table 2). These three pesticides also were some of the most frequently applied pesticides in 1989 (Tornes and Brigham, 1994). Changes in pesticide use may be the result of a number of causes, including pest outbreaks, changes in pest populations, tillage practices, changes between nonchemical and chemical methods, changes in the acreage of major crops, or new developments in pest control technology (Zollinger and others, 2006).

Pesticide applications reported in table 2 are for the entire States of Minnesota and North Dakota and are not limited to the Red River Basin. Application rates specifically for the Red River Basin were not available. However, it is likely that the amounts and types of pesticides applied are different than the statewide applications due to the different crops grown in the region. For example, atrazine was one of the most widely applied pesticides (in acres treated) for the State of Minnesota. However, atrazine is applied mainly to corn crops and much of the corn is grown in the southern half of the State, south of the Red River Basin. It is important to consider this when comparing the pesticide applications in table 2 to pesticides detected in surface and ground water in the Red River Basin.

Erosion is a concern in many agricultural regions and it can be influenced by many factors. Tornes and Brigham (1994) noted that the Red River Valley was affected by many agricultural factors, including the frequency and timing of tillage, tillage of steep lands and gullies, direction of plowing with respect to the land slope, and overgrazing, which can damage plant cover. Many best management practices have been put into place to minimize erosion. These include reduced-tillage farming methods, contour farming, buffer strips along streams, cover crops, and conservation reserve programs.

Agricultural land is not the only source of pesticides that are transported to the waters of the basin. Many pesticides are applied to residential lawns, parks, and golf courses. Furthermore, land that is removed from agricultural production and planted in native grasses often is treated with pesticides to control the spread of weeds to nearby crops. These applications often are not well documented.

**Table 1.** Estimates of fertilizer application for counties in the Red River of the North Basin, 2002.

[Modified from U.S. Department of Agriculture (2002).]

| County | Acres treated with commercial fertilizer | Acres treated with manure | Total | Percentage of county area (farms only) treated with fertilizer[1] |
|---|---|---|---|---|
| Minnesota | | | | |
| Becker | 143,300 | 23,000 | 166,300 | 20 |
| Beltrami | 29,000 | 7,300 | 36,300 | 2.3 |
| Big Stone | 154,100 | 5,000 | 159,100 | 50 |
| Clay | 367,700 | 10,000 | 377,700 | 57 |
| Clearwater | 52,600 | 4,700 | 57,300 | 9.0 |
| Grant | 197,600 | 3,600 | 201,200 | 58 |
| Itasca | 10,700 | 3,600 | 14,300 | 0.8 |
| Kittson | 338,900 | 6,600 | 345,500 | 49 |
| Koochiching | 8,100 | 1,700 | 9,800 | 0.5 |
| Lake of the Woods | 49,500 | 1,300 | 50,800 | 6.1 |
| Mahnomen | 107,900 | 7,300 | 115,200 | 32 |
| Marshall | 496,300 | 6,700 | 503,000 | 44 |
| Norman | 380,800 | 6,900 | 387,700 | 69 |
| Otter Tail | 313,200 | 71,600 | 384,800 | 30 |
| Pennington | 143,700 | 1,900 | 145,600 | 37 |
| Polk | 742,100 | 10,200 | 752,300 | 60 |
| Red Lake | 117,900 | 4,100 | 122,000 | 44 |
| Roseau | 320,900 | 12,100 | 333,000 | 31 |
| Stevens | 188,700 | 22,300 | 211,000 | 59 |
| Traverse | 212,000 | 6,600 | 218,600 | 60 |
| Wilkin | 281,300 | 8,800 | 290,100 | 60 |

**Table 1.** Estimates of fertilizer application for counties in the Red River of the North Basin, 2002.—Continued

[Modified from U.S. Department of Agriculture (2002).]

| County | Acres treated with commercial fertilizer | Acres treated with manure | Total | Percentage of county area (farms only) treated with fertilizer[1] |
|---|---|---|---|---|
| North Dakota | | | | |
| Barnes | 540,100 | 4,400 | 544,500 | 57 |
| Benson | 387,900 | 4,900 | 392,800 | 44 |
| Cass | 748,500 | 4,300 | 752,800 | 67 |
| Cavalier | 649,900 | 600 | 650,400 | 68 |
| Eddy | 117,500 | 3,500 | 120,900 | 30 |
| Foster | 219,600 | 1,900 | 221,400 | 55 |
| Grand Forks | 548,600 | 2,100 | 550,700 | 60 |
| Griggs | 186,800 | 900 | 187,700 | 41 |
| Nelson | 286,800 | 1,900 | 288,700 | 46 |
| Pembina | 480,500 | 1,500 | 482,000 | 67 |
| Pierce | 239,100 | 5,000 | 244,100 | 38 |
| Ransom | 212,300 | 7,100 | 219,400 | 40 |
| Richland | 589,100 | 7,400 | 596,600 | 65 |
| Rolette | 189,900 | 2,900 | 192,900 | 33 |
| Sargent | 254,500 | 4,100 | 258,600 | 47 |
| Sheridan | 211,700 | 2,800 | 214,500 | 35 |
| Steele | 288,800 | 800 | 289,600 | 64 |
| Towner | 312,000 | 2,500 | 314,500 | 48 |
| Traill | 420,800 | 1,600 | 422,400 | 77 |

[1] Fertilizer application to land other than farms (for example golf courses and residences) was not included.

**Table 2.** Pesticide applications in Minnesota and North Dakota, 1997.

[Data from the National Center for Food and Agricultural Policy described in Gianessi and Marcelli (2004) and available at *http://www.ncfap.org*; all values in thousands; pesticides are in order of decreasing total (Minnesota plus North Dakota) acres treated; MCPA, methyl chlorophenoxy acetic acid; —, no data; EPTC, dipropyl thiocarbamic acid s-ethyl ester; <, less than]

| Pesticide | Crops | Minnesota | | North Dakota | |
|---|---|---|---|---|---|
| | | Acres treated | Pounds applied | Acres treated | Pounds applied |
| **Herbicides** | | | | | |
| 2,4-D | Barley, corn, fallow land, flax, millet; oats, hay, pasture, rye, soybeans, wheat | 2,463 | 711 | 7727 | 2,188 |
| MCPA | Barley, flax, oats, rye, wheat | 2,078 | 845 | 6,759 | 2,304 |
| Dicamba | Barley, corn, fallow land, flax, millet, oats, wheat | 3,093 | 1,137 | 5,209 | 525 |
| Trifluralin | Alfalfa, barley, canola, dry beans, fallow land, flax, potatoes, soybeans, sugarbeets, sunflowers, wheat | 2,509 | 2,073 | 3,586 | 1,928 |
| Fenoxaprop | Barley, soybeans, wheat | 1,744 | 134 | 4,121 | 251 |
| Imazethapyr | Corn, dry beans, soybeans | 4,583 | 184 | 533 | 26 |
| Tribenuron | Barley, oats, wheat | 598 | 2 | 4,138 | 25 |
| Clopyralid | Barley, canola, corn, sugarbeets, wheat | 1,379 | 176 | 2,470 | 267 |
| Atrazine | Corn | 3,199 | 1,982 | 186 | 186 |
| Glyphosate | Alfalfa, barley, corn, fallow land, flax, oats, potatoes, rye, soybeans, sugarbeets, sunflowers, wheat | 460 | 388 | 2,762 | 1,241 |
| Bromoxynil | Barley, corn, flax, oats, rye, wheat | 1,498 | 374 | 1,496 | 374 |
| Thifensulfuron | Barley, corn, oats, soybeans, wheat | 1,553 | 9 | 1,286 | 11 |
| Nicosulfuron | Corn, sweet corn | 2,145 | 43 | 334 | 8 |
| Acetochlor | Corn | 1,866 | 2,968 | 149 | 204 |
| Metolachlor | Corn, potatoes, soybeans | 1,730 | 3,550 | 30 | 69 |
| Bentazon | Corn, dry beans, soybeans | 887 | 654 | 675 | 506 |
| Quizalofop | Canola, dry beans, soybean, sugarbeets | 1,150 | 62 | 410 | 26 |
| Sethoxydim | Alfalfa, canola, dry beans, flax, green beans, green peas, onion, potatoes, strawberries, soybeans, sunflowers | 863 | 122 | 514 | 107 |
| Pendimethalin | Corn, potatoes, soybeans, sunflowers | 1,203 | 1,368 | 147 | 186 |
| Ethalfluralin | Canola, dry beans, soybeans, sunflowers | 69 | 58 | 1,248 | 972 |
| Clethodim | Soybeans, sugarbeets | 765 | 61 | 341 | 25 |
| Flumetsulam | Corn, soybeans | 847 | 30 | 79 | 4 |
| Primisulfuron | Corn | 867 | 17 | — | — |
| Desmedipham | Sugarbeets | 456 | 73 | 235 | 38 |
| Phenmedipham | Soybeans | 456 | 68 | 235 | 35 |
| Triflusulfuron | Sugarbeets | 456 | 9 | 235 | 5 |
| Acifluorfen | Soybeans | 494 | 123 | 128 | 38 |
| Imazamethabenz | Barley, sunflowers, wheat | 141 | 40 | 461 | 155 |
| Lactofen | Soybeans | 370 | 37 | 128 | 9 |
| Fomesafen | Soybeans | 432 | 82 | 53 | 10 |

**Table 2.** Pesticide applications in Minnesota and North Dakota, 1997.—Continued

[Data from the National Center for Food and Agricultural Policy described in Gianessi and Marcelli (2004) and available at *http://www.ncfap.org*; all values in thousands; pesticides are in order of decreasing total (Minnesota plus North Dakota) acres treated; MCPA, methyl chlorophenoxy acetic acid; —, no data; EPTC, dipropyl thiocarbamic acid s-ethyl ester; <, less than]

| Pesticide | Crops | Minnesota | | North Dakota | |
|---|---|---|---|---|---|
| | | Acres treated | Pounds applied | Acres treated | Pounds applied |
| Herbicides—Continued | | | | | |
| EPTC | Alfalfa, corn, potatoes, sugarbeets, sunflowers | 294 | 1090 | 178 | 642 |
| Alachlor | Corn, soybeans | 422 | 1179 | 39 | 92 |
| Cyanazine | Corn | 414 | 475 | 37 | 44 |
| Dimenthenamid | Corn, soybeans | 365 | 316 | 75 | 102 |
| Diclofop | Barley, wheat | 91 | 65 | 326 | 230 |
| Fluazifop | Soybeans | 373 | 34 | 32 | 6 |
| Prosulfuron | Corn | 400 | 8 | — | — |
| Triallate | Barley, flax, wheat | 113 | 113 | 283 | 283 |
| Metsulfuron | Barley, wheat | 1 | <1 | 370 | 1 |
| Picloram | Barley, flax, oats, hay, pasture | 72 | 9 | 264 | 51 |
| Chlorsulfuron | Barley, oats, wheat | — | — | 282 | 3 |
| Paraquat | Corn, dry beans, potatoes, soybeans, sugarbeets | 128 | 52 | 133 | 29 |
| Chlorimuron | Soybeans | 247 | 2 | — | — |
| Triasulfuron | Fallow land, wheat | — | — | 238 | 2 |
| Metribuzin | Potatoes, soybeans | 157 | 29 | 79 | 27 |
| Difenzoquat | Barley, wheat | 89 | 59 | 131 | 99 |
| Ethofumesate | Sugarbeets | 137 | 34 | 75 | 19 |
| Rimsulfuron | Corn | 133 | 1 | 53 | 1 |
| Cycloate | Sugarbeets | 105 | 315 | 54 | 135 |
| Clomazone | Green peas, pumpkin, soybeans | 139 | 102 | — | — |
| Halosulfuron | Corn | 133 | 4 | — | — |
| Diquat | Potatoes | 59 | 18 | 37 | 17 |
| Flumiclorac | Soybeans | 62 | 2 | — | — |
| 2,4-DB | Alfalfa | 22 | 16 | 13 | 14 |
| Linuron | Potatoes | 7 | 9 | 18 | 18 |
| Endothall | Potatoes, sugarbeets | 16 | 10 | 6 | 3 |
| Hexazinone | Alfalfa | 13 | 10 | — | — |
| MCPB | Green peas | 10 | 8 | — | — |
| Propachlor | Corn, sweet corn | 6 | 12 | — | — |
| MCPP | Sod | 4 | 1 | — | — |
| Simazine | Apples | 1 | 2 | — | — |
| DCPA | Onions | <1 | <1 | — | — |
| Diuron | Apples | <1 | 1 | — | — |

**Table 2.** Pesticide applications in Minnesota and North Dakota, 1997.—Continued

[Data from the National Center for Food and Agricultural Policy described in Gianessi and Marcelli (2004) and available at *http://www.ncfap.org*; all values in thousands; pesticides are in order of decreasing total (Minnesota plus North Dakota) acres treated; MCPA, methyl chlorophenoxy acetic acid; —, no data; EPTC, dipropyl thiocarbamic acid s-ethyl ester; <, less than]

| Pesticide | Crops | Minnesota | | North Dakota | |
|---|---|---|---|---|---|
| | | Acres treated | Pounds applied | Acres treated | Pounds applied |
| | **Herbicides—Continued** | | | | |
| Napropamide | Strawberries | <1 | 1 | — | — |
| Oxyfluorfen | Onions | <1 | <1 | — | — |
| Terbacil | Strawberries | <1 | <1 | — | — |
| | **Fungicides** | | | | |
| Tebuconazole | Wheat | 502 | 60 | 783 | 86 |
| Mancozeb | Barley, potatoes, sugarbeets, wheat | 331 | 990 | 316 | 636 |
| Propiconazole | Barley, dry beans, sweet corn, wheat, wild rice | 338 | 46 | 280 | 34 |
| Triphenyltinhyd | Potatoes, sugarbeets | 334 | 243 | 164 | 117 |
| Thiophanate methyl | Dry beans, sugarbeets | 118 | 70 | 139 | 9 |
| Benomyl | Dry beans, sugarbeets, wheat | 62 | 43 | 174 | 74 |
| Chlorothalonil | Dry beans, potatoes | 69 | 288 | 113 | 767 |
| Maneb | Dry beans, potatoes, sugarbeets | 73 | 156 | 54 | 91 |
| Metalaxyl | Potatoes | 7 | 2 | 45 | 9 |
| Copper | Potatoes | 21 | 32 | 7 | 7 |
| Cymoxanil | Potatoes | 13 | 3 | 14 | 2 |
| Propamocarb | Potatoes | 14 | 12 | 10 | 9 |
| Metiram | Potatoes | 8 | 31 | 10 | 47 |
| Captan | Apples, pumpkin, strawberries | 4 | 38 | — | — |
| Dimethomorph | Potatoes | 4 | 1 | — | — |
| Myclobutanil | Apples | 3 | 1 | — | — |
| Iprodione | Onions | 1 | 1 | — | — |
| Vinclozolin | Green beans, onions, strawberries | 1 | 1 | — | — |
| Fenarimol | Apples | <1 | <1 | — | — |
| Streptomycin | Apples | <1 | <1 | — | — |
| | **Insecticides** | | | | |
| Chlorpyrifos | Barley, sugarbeets, wheat | 400 | 424 | 473 | 250 |
| Esfenvalerate | Dry beans, potatoes, soybeans, sunflowers | 53 | 2 | 572 | 23 |
| Terbufos | Corn, soybeans, sweet corn | 451 | 457 | 162 | 187 |
| Permethrin | Alfalfa, apples, corn, onions, potatoes, pumpkins, sweet corn | 122 | 42 | 299 | 63 |
| Lambdacyhalothrin | Canola, corn, sunflowers | 45 | 2 | 236 | 7 |
| Tefluthrin | Corn, sweet corn | 272 | 22 | 7 | 1 |
| Phorate | Corn, potatoes | 141 | 143 | 60 | 103 |

**Table 2.** Pesticide applications in Minnesota and North Dakota, 1997.—Continued

[Data from the National Center for Food and Agricultural Policy described in Gianessi and Marcelli (2004) and available at *http://www.ncfap.org*; all values in thousands; pesticides are in order of decreasing total (Minnesota plus North Dakota) acres treated; MCPA, methyl chlorophenoxy acetic acid; —, no data; EPTC, dipropyl thiocarbamic acid s-ethyl ester; <, less than]

| Pesticide | Crops | Minnesota | | North Dakota | |
|---|---|---|---|---|---|
| | | Acres treated | Pounds applied | Acres treated | Pounds applied |
| | **Insecticides—Continued** | | | | |
| Carbofuran | Alfalfa, canola, potatoes, sunflowers | 44 | 27 | 112 | 52 |
| Carbaryl | Canola, potatoes, sugarbeets, sunflowers, | 27 | 28 | 51 | 64 |
| Dimethoate | Alfalfa, potatoes | 29 | 11 | 38 | 19 |
| Azinphos-methyl | Potatoes | 51 | 31 | 12 | 6 |
| Endosulfan | Potatoes | 48 | 22 | 14 | 13 |
| Methyl Parathion | Potatoes, sunflowers | 29 | 13 | 22 | 38 |
| Methamidophos | Potatoes | 14 | 10 | 11 | 23 |
| Ethyl Parathion | Oats, sunflowers | — | — | 18 | 16 |
| Imidacloprid | Potatoes | 14 | 2 | 1 | <1 |
| Malathion | Barley, strawberries, sugarbeets, wild rice | 14 | 13 | — | — |
| Tralomethrin | Soybeans, sunflowers | — | — | 13 | 1 |
| Ethoprop | Potatoes | — | — | 11 | 45 |
| Cyfluthrin | Sweet corn | 9 | 1 | — | — |
| Methomyl | Sweet corn | 8 | 4 | — | — |
| Acephate | Green beans | 5 | 4 | — | — |
| Oxamyl | Potatoes | 5 | 2 | — | — |
| Phosmet | Apples | 3 | 12 | — | — |
| Oil | Apples | 2 | 37 | — | — |
| Cypermethrin | Onions | <1 | <1 | — | — |
| Hexythiazox | Apples | <1 | <1 | — | — |
| | **Other pesticides[1]** | | | | |
| Sodium Chlorate | Dry beans | 15 | 44 | 12 | 35 |
| Sulfuric Acid | Potatoes | 4 | 514 | 10 | 1403 |
| Metam sodium | Potatoes | 13 | 1581 | — | — |
| Maleic Hydrazide | Potatoes | 4 | 7 | 5 | 10 |
| Chloropicrin | Strawberries | <1 | 6 | — | — |
| Methyl Bromide | Strawberries | <1 | 31 | — | — |
| NAA | Apples | <1 | <1 | — | — |

[1]Other pesticides are fumigants, growth regulators, and defoliants.

# Methods

Data for this report came from several different sources, primarily the USEPA's STORET (STOrage and RETrieval) data base (*http://www.epa.gov/storet/dbtop.html*) and the U.S. Geological Survey NWIS (National Water Information System) data base (http://waterdata.usgs.gov/nwis). Data in STORET are provided by many agencies and processed by the MPCA and NDDH. Additional ground-water data were obtained from Minnesota Department of Natural Resources (MDNR), the North Dakota State Water Commission (ND SWC), and the Minnesota Department of Agriculture (MDA).

The concentrations of constituents provided in this report are dependent on sampling and analytical methods. Sampling and analytical methods can vary among agencies and over time. These differences can confound direct comparison of water-quality data as methods change and improve. In addition, improvements in analytical methods can result in lower detection limits, and therefore lower reporting levels (Tornes and Brigham, 1994). Improved methods can yield data that, when combined with earlier data, show false downward temporal trends in chemical concentrations (Flegal and Coale, 1989).

In addition, different agencies may use different reporting levels in electronic data bases. For USGS data, reporting levels provided in the NWIS data base are the smallest concentration of a constituent that may be reported by using a given analytical method (Timme, 1995). The STORET data base reports detection limits. The USEPA defines a detection limit as the minimum concentration of a substance that can be measured and reported with 99-percent confidence that the analyte concentration is greater than zero (U.S. Environmental Protection Agency, 1997).

With the exception of the USGS data, no attempt was made to research the quality-assurance procedures used by the agencies that collected and analyzed the data presented in this report. For USGS data, in addition to the quality-control samples submitted from the field (Wershaw and others, 1987; Edwards and Glysson, 1988; Ward and Harr, 1990; and Horowitz and others, 1994), internal quality-assurance practices at the USGS National Water-Quality Laboratory (NWQL) included analysis of calibration standards, standard-reference samples, replicate samples, blanks, and spikes (Pritt and Raese, 1995).

In general, reporting levels, detection limits, and concentration values are reported uncensored as they are found in their respective data bases. The one exception is nitrate values. Nitrate was reported differently by different agencies. The values of nitrate reported for USGS and ND SWC well sites were nitrite plus nitrate. Both agencies have determined that the nitrite concentrations in ground water were negligible, and, therefore, concentrations of nitrite plus nitrate in ground water are reported here as nitrate. In addition, the ND SWC reports values of nitrate as nitrate (Bill Shuh, North Dakota State Water Commission, oral commun., October 15, 2006). Therefore, a conversion factor of 0.2258 was used to convert the nitrate as nitrate concentrations to nitrate as nitrogen for this report. The ND SWC laboratory changed nitrate methods in the early 1990s. No adjustment was made to the data to account for this method change.

To optimize comparability between sites and facilitate comparison to the earlier report (Tornes and Brigham, 1994), certain criteria were used to determine which surface-water sites were to be included in this analysis. These selection criteria were: (1) the site must have had at least 2 years of data collected over two sampling seasons, generally from about March through October, within the 1990–2004 time period, and (2) at least 8 samples from the site were analyzed for the constituent evaluated. The surface-water sites included in this report are listed in table 3 (USGS sites) and table 4 (STORET sites).

Many ground-water sites did not meet the same selection criteria as the surface-water sites of a minimum of 8 samples over 2 years. The study area has more ground-water wells than surface-water sampling sites. A large number of wells were sampled only a few times during 1990 through 2004; therefore, in order to evaluate nutrient concentrations, ground-water sites were grouped by county.

Several agencies throughout the Red River Basin have collected and analyzed ground-water samples. In North Dakota, most of the samples have been collected and analyzed by the ND SWC. Through cooperative studies, the USGS also has collected and analyzed some samples on the North Dakota side of the basin. Most of the ground-water samples from the Minnesota side of the basin were collected and analyzed by the USGS and the results are available from the NWIS data base. Some samples from Minnesota were collected and analyzed by the MDA, MDNR, or the MPCA's Ground Water Monitoring Assessment Program (GWMAP). Generally, very little Red River Basin ground-water nutrient and pesticide data were available from STORET.

The spatial distribution of ground-water wells sampled for nutrients was variable and no or very few wells were sampled in several counties (fig. 7). Samples were collected from more than 300 wells during 1990–2004 in Grand Forks, McHenry, Ransom, and Sargent Counties, N. Dak. In general, more wells in the basin were sampled in North Dakota than in Minnesota, and many of the wells in North Dakota had numerous nutrient samples because they were part of a long-term sampling program.

Data in this report generally are summarized as box plots truncated at the 10th and 90th percentiles (Helsel and Hirsch, 1992). Box plots are a good visual representation of range, central tendency, and skewness. By truncating the box plots, extreme values are not displayed. The exceptions are ground-water nitrate concentrations (because of the limited data available for Minnesota counties) and surface-water suspended-sediment concentrations, where all values for a site are shown. For a standard boxplot, the upper (or lower) adjacent value is defined as the largest (or smallest) observation within one step of the 75th percentile (Helsel and Hirsch, 1992). A step is 1.5 times the interquartile range. Upper (or lower) outside values are between 1 and 2 steps above (or below) the 75th percentile and upper (or lower) detached values are more than 2 steps above (or below) the 75th percentile.

**Table 3.** Selected U. S. Geological Survey surface-water sites sampled for streamflow or analysis of nutrients, suspended sediment, and pesticides.

[Sites are listed in downstream order; DD, degrees; MM, minutes; SS, seconds]

| Map site identifier | USGS identifier (fig. 3) | Site name | Latitude DD MM SS | Longitude DD MM SS |
|---|---|---|---|---|
| 1 | 05030150 | Otter Tail River near Perham, Minn. | 46 38 34 | 095 36 15 |
| 2 | 05030181 | Otter Tail River at Little Pine Lake Outlet near Perham, Minn. | 46 37 36 | 095 32 23 |
| 3 | 05030245 | Toad River at Dead Lake Outlet near Perham, Minn | 46 42 33 | 095 33 11 |
| 4 | 05030270 | Toad River at Big Pine Lake Inlet near Perham, Minn. | 46 28 39 | 095 30 37 |
| 5 | 05030290 | Otter Tail River at Big Pine Lake Outlet near Perham, Minn. | 46 35 31 | 095 30 13 |
| 6 | 05046000 | Otter Tail River below Orwell Dam near Fergus Falls, Minn. | 46 12 35 | 096 11 05 |
| 7 | 05051300 | Bois de Sioux River near Doran, Minn. | 46 09 08 | 096 34 44 |
| 8 | 05051510 | Red River of the North below Wahpeton, N. Dak. | 46 22 30 | 096 39 25 |
| 9 | 05051522 | Red River of the North at Hickson, N. Dak. | 46 39 35 | 096 47 44 |
| 10 | 05054000 | Red River of the North at Fargo, N. Dak. | 46 51 40 | 096 47 00 |
| 11 | 05054200 | Red River of the North near Harwood, N. Dak. | 46 58 37 | 096 49 14 |
| 12 | 05056000 | Sheyenne River near Warwick, N. Dak. | 47 48 20 | 098 42 57 |
| 13 | 05056100 | Mauvais Coulee near Cando, N. Dak. | 48 26 53 | 099 06 08 |
| 14 | 05056200 | Edmore Coulee near Edmore, N. Dak. | 48 20 12 | 098 39 36 |
| 15 | 05056220 | Sweetwater Lake at Sweetwater, N. Dak. | 48 12 39 | 098 52 15 |
| 16 | 05056239 | Starkweather Coulee near Webster, N. Dak. | 48 19 14 | 098 56 25 |
| 17 | 05056270 | Big Coulee below Churchs Ferry, N. Dak. | 48 15 33 | 099 12 00 |
| 18 | 05056400 | Big Coulee near Churchs Ferry, N. Dak. | 48 10 40 | 099 13 15 |
| 19 | 05056402 | Big Coulee near Minnewaukan, N. Dak. | 48 06 55 | 099 07 03 |
| 20 | 05056404 | Big Coulee at Devils Lake Inlet near Minnewaukan, N. Dak. | 48 03 55 | 099 09 21 |
| 21 | 05056410 | Channel A near Penn, N. Dak. | 48 10 00 | 098 58 47 |
| 22 | 05058700 | Sheyenne River at Lisbon, N. Dak. | 46 26 49 | 097 40 44 |
| 23 | 05059000 | Sheyenne River near Kindred, N. Dak. | 46 37 54 | 097 00 01 |
| 24 | 05060400 | Sheyenne River at Harwood, N. Dak. | 46 58 39 | 096 53 29 |

**Table 3.** Selected U. S. Geological Survey surface-water sites sampled for streamflow or analysis of nutrients, suspended sediment, and pesticides. —Continued

[Sites are listed in downstream order; DD, degrees; MM, minutes; SS, seconds]

| Map site identifier | USGS identifier (fig. 3) | Site name | Latitude DD MM SS | Longitude DD MM SS |
|---|---|---|---|---|
| 25 | 05062500 | Wild Rice River at Twin Valley, Minn. | 47 16 00 | 096 14 40 |
| 26 | 05064000 | Wild Rice River at Hendrum, Minn. | 47 16 05 | 096 47 50 |
| 27 | 05064500 | Red River of the North at Halstad, Minn. | 47 21 07 | 096 50 36 |
| 28 | 05064900 | Beaver Creek near Finley, N. Dak. | 47 35 41 | 097 42 33 |
| 29 | 05078470 | Judicial Ditch 64 near Mentor, Minn. (SW4) | 47 44 16 | 096 12 09 |
| 30 | 05078520 | Cyr Creek near Marcoux Corners, Minn. (SW5) | 47 48 13 | 096 16 36 |
| 31 | 05078730 | County Ditch 140 near Benoit, Minn. (SW1) | 47 41 15 | 096 22 22 |
| 32 | 05078770 | Judicial Ditch 66 near Marcoux Corners, Minn. (SW6) | 47 46 55 | 096 19 53 |
| 33 | 05079000 | Red Lake River at Crookston, Minn. | 47 46 32 | 096 36 33 |
| 34 | 05079200 | County Ditch 72 (Burnham Creek) near Maple Bay, Minn. (SW3) | 47 36 43 | 096 16 45 |
| 35 | 05079250 | County Ditch 65 near Maple Bay, Minn. (SW2) | 47 36 43 | 096 16 45 |
| 36 | 05082500 | Red River of the North at Grand Forks, N. Dak. | 47 55 37 | 097 01 44 |
| 37 | 05082625 | Turtle River at Turtle River State Park near Arvilla, N. Dak. | 47 55 55 | 097 30 51 |
| 38 | 05085900 | Snake River above Alvarado, Minn. | 48 10 27 | 096 59 55 |
| 39 | 05099400 | Little South Pembina River near Walhalla, N. Dak. | 48 51 55 | 098 00 20 |
| 40 | 05099600 | Pembina River at Walhalla, N. Dak. | 48 54 48 | 097 55 00 |
| 41 | 05099900 | Pembina River above Neche, N. Dak. | 48 57 49 | 097 41 14 |
| 42 | 05100100 | Pembina River below Neche, N. Dak. | 48 57 23 | 097 24 12 |
| 43 | 05100460 | Tongue River near Olga, N. Dak. | 48 45 40 | 098 06 11 |
| 44 | 05100480 | Tongue River below Young Dam near Concrete, N. Dak. | 48 45 18 | 098 00 50 |
| 45 | 05100800 | Tongue River above Renwick Dam near Akra, N. Dak. | 48 46 44 | 097 47 42 |
| 46 | 05101000 | Tongue River at Akra, N. Dak. | 48 46 42 | 097 44 47 |
| 47 | 05102490 | Red River of the North at Pembina, N. Dak. | 48 58 37 | 097 14 14 |
| 48 | 05112000 | Roseau River below State Ditch 51 near Caribou, Minn. | 48 58 54 | 096 27 46 |

**Table 4.** Selected U.S. Environmental Protection Agency STORage and RETrieval System surface-water sites sampled for analysis of nutrients, suspended sediment, or pesticides (listed in downstream order).

[Sites are listed in downstream order; STORET, U.S. Environmental Protection Agency Storage and Retrieval System ; DD, degrees; MM, minutes; SS, seconds]

| Map site identifier | STORET identifier | Site name | Latitude DD MM SS | Longitude DD MM SS |
|---|---|---|---|---|
| S1 | S002-001 | Mustinka River at CSAH-9 Bridge, 1.3 mi NW of Norcross, Minn. | 45 53 15 | 096 12 48 |
| S2 | S002-002 | Rabbit River at CSAH-4 right bank of bridge, 0.1 mi southwest of Campbell, Minn. | 46 05 43 | 096 24 38 |
| S3 | 380001 | Bois de Sioux River at Wahpeton, N. Dak. | 46 15 50 | 096 35 56 |
| S4 | S002-170 | Pelican River at Long Avenue in Detroit Lakes, Minn. | 46 48 37 | 095 49 43 |
| S5 | S000-111 | Otter Tail River Bridge on CSAH-15 west of Fergus Falls, Minn. | 46 16 32 | 096 08 04 |
| S6 | 380083 | Red River of the North at Brushville, Minn. | 46 22 10 | 096 39 24 |
| S7 | S002-114 | Red River of the North on CR-8, 9 mi south of Moorhead, Minn. | 46 43 52 | 096 47 02 |
| S8 | 385234 | Wild Rice River, N. Dak. | 46 13 04 | 097 15 34 |
| S9 | 380154 | Red River of the North, south of Fargo, N. Dak. | 46 50 52 | 096 46 50 |
| S10 | S000-183 | Red River of the North Bridge on Main Avenue at 3rd Street, Moorhead, Minn. | 46 52 26 | 096 46 35 |
| S11 | 385040 | Red River of the North near Harwood, N. Dak. | 46 58 37 | 096 49 13 |
| S12 | 380033 | Bald Hill Creek at Dazey, N. Dak. | 47 10 58 | 098 04 12 |
| S13 | 380135 | Sheyenne River southwest of Harvey, N. Dak. | 47 42 09 | 099 56 56 |
| S14 | 384155 | Maple River at Mapleton, N. Dak. | 46 54 19 | 097 03 09 |
| S15 | 380156 | Goose River at Hillsboro, N. Dak. | 47 24 25 | 097 03 27 |
| S16 | 384156 | Red River of the North at Grand Forks, N. Dak. | 47 55 37 | 097 01 42 |
| S17 | 380037 | Turtle River north of Manvel, N. Dak. | 48 05 10 | 097 11 03 |
| S18 | 380040 | Forest River east of Minto, N. Dak. | 48 18 30 | 097 11 21 |
| S19 | 380046 | Park River at Highway I-29, N. Dak. | 48 27 36 | 097 11 00 |
| S20 | 380004 | Red River at Drayton, N. Dak. | 48 34 22 | 097 08 53 |
| S21 | S002-370 | Two Rivers, North Branch at US-75 at Northcote, Minn. | 48 50 59 | 097 00 20 |
| S22 | 380011 | Pembina River at Walhalla, N. Dak. | 48 54 49 | 097 55 00 |
| S23 | 384157 | Red River at Pembina, N. Dak. | 48 58 39 | 097 14 18 |